PROBLEM-SOLVING BY MATURE RATS AS CONDITIONED BY THE LENGTH, AND AGE AT IMPOSITION, OF EARLIER FREE-ENVIRONMENTAL EXPERIENCE

By

BERNARD EINGOLD

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CHAPTER I

INTRODUCTION

The problem of childhood experience and its effect on adult behavior is one which has been of constant interest to man. Philosophical, religious, and political figures, and students of behavior have all elaborated relevant principles many of which were considered final and definitive.

Reasons for the lasting interest in this problem are not difficult to uncover. Casting science and its constant thirst for knowledge aside for the moment, the problem appears to have implications in many areas of life. Religious and philosophical leaders are concerned with moral issues and ethical values. Political figures attempt to instill in their subjects a way of life which will preserve the nation's culture and heritage. In short all are concerned with the development and maintenance of certain ideas, values, goals, and purposes. In many, if not in most, instances the young child has been the target of this training. The leaders have long assumed that knowledge obtained in childhood or the effects of early experience are fairly permanent and long lasting.

The proposition that early experience has an effect on later behavior implies that child rearing practices are of extreme importance and that some or many of their effects will be seen in subsequent years. Freud was one of the first to emphasize and treat this implication in a systematic fashion. Watson, too, although his theoretical approach to the subject was completely different, emphasized this period of life. He is credited with the statement that were he permitted to rear a child and to determine the experiences it would have, the child would later become whatever he, Watson, had previously decided upon, be it doctor, lawyer, merchant, chief or beggar.

Although this assertion may be viewed as optimistic, naive, or one-sided, it does indicate the importance attached to environmental influences by some psychologists. However, it cannot be dismissed glibly with a comment about its naïveté. It may be true that the range indicated may not be open to the individual, but that which is available under normal conditions is indeed wide. The problem requires the imposition of certain environmental variables during the developmental stages and testing their effects on behavior at maturity. A task of this sort is a practical impossibility if children were to be used as experimental subjects. Equating them genetically and controlling the environment in such a way as to meet experimental standards would be impossible. Finally, the time required would make such a study impracticable.

The rat appears to be a subject excellently suited for research of this type. Practically pure, in-bred strains are available; control of the environment is not difficult; and they are mature at the age of ninety days. For these reasons rats were selected for the present study, an investigation aimed at providing a single experimental variable and determining its effect on subsequent behavior. Rats were selected with the knowledge that generalizations to human development and behavior must be guarded, however, it was felt that strict experimental control was of major importance.

The specific purpose of the present study is to test the following hypothesis: The effect of free-environmental experience on problem-solving ability of mature rats is a function of the length of this experience and the age at which it is permitted.

CHAPTER II

REVIEW OF THE LITERATURE

Comprehensive reviews of investigations covering early experience and its effect on subsequent behavior in both human (15) and animal (1) subjects have appeared in the literature recently. Studies of human nursing experiences, finger-sucking, restraint of movement, social isolation, etc., are not pertinent to the present study, and most of the animal research reported in the review by Beach and Jaynes (1) is, at best, of tangential importance. The literature reported below is, therefore, restricted to those studies from which the present investigation directly stems.

Scattered studies appeared early, but the first major problem that arose in this general area was the attempt to determine the relative importance of maturation and practice in the perfection of responses. Shepard and Breed (19), working with pecking behavior in chickens, reported one of the first studies concerned with this problem. Interest continued to grow and was afforded further impetus in 1926 when the first of Carmichael's studies on the swimming behavior of larval amphibians was published (4). Although interest in the problem of early experience and its effect on future behavior never has waned, renewed and greater interest was stirred in present day psychology as a result of theories stressing the importance of perceptual learning in early life. "A leader in this field is Hebb, whose The Organization of Behavior has been directly or indirectly responsible for a number of experiments reported in psychological journals during the past two or three years" (1, p. 240).

In an attempt to learn more concerning the effect of early learning on mature behavior, Hebb (8, 9) conducted exploratory research. It was labelled as such because it, "was not certain that such effects could be found in rat behavior, even if they exist for man; but if one could find some trace of them in rat behavior their nature could be investigated much more easily in a species that reaches maturity in three months than in one that takes fifteen years" (9, p. 296-297). In a first study it was found that rats blinded at maturity, 90 days of age, were superior to litter mates blinded in infancy when tested on the Hebb-Williams apparatus. No differences in performance were observed on two rote learning tasks requiring 200 or more trials for mastery. It was also found that these differences were relatively permanent; at eight months of age, five months after being blinded, the late-blinded group was still superior. A second study, also exploratory in nature, compared animals reared in ordinary laboratory cages with a group reared at home as pets. The latter group was superior on the Hebb-Williams test. The conclusions drawn from this work were that infant experience has a lasting effect on problem-solving behavior in the rat and that this effect is not detectable from rote learning scores. Such an effect appears when a method similar to a human intelligence test is used--that is, one yielding an index based on a large number of problems.

Although his interpretation was in terms of the animals' early perceptual experience, Hebb (9) indicates that the differences between the cage- and pet-reared groups may be interpreted by some as a result of the pet group being tamer, more used to handling, and less disturbed by testing in general. But if this is true the longer testing proceeded the better the cage-reared animals should have become in relation to the pet group. However, just the reverse occurred; the pet group maintained and increased its superiority. "This means that the <u>richer experience of the pet group, during development, made them better able to profit by new experiences at maturity</u>--one of the characteristics of the 'intelligent' human being" (9, p. 298-299).

Two studies add weight to the argument that the relationship to the experimenter was of major importance in producing the superior performance of the pet group.

Shurrager (20), in a discussion of why some of his "spinal" cats partially regained their ability to walk, prefers this explanation to all others. He describes at length the type of close relationship that existed between experimenter and animal and feels that this relationship was the main factor in their recovery. Bernstein (2) starting with this hypothesis raised two groups of rats identically, except that the experimental group was handled a great deal. When faced with a discrimination task the experimental animals made significantly fewer errors. Qualitatively, they showed more exploratory behavior throughout the study as well as more activity in their home cages. These findings suggested to Bernstein an alternate interpretation to Hebb's emphasis on "early exploratory experience," and he hypothesized that, with early experience held constant, the group of animals petted and handled by the experimenter would show learning superior to that of animals that have broad exploratory experience only.

Because Hebb's work was exploratory and conducted to determine if any effects could be elicited, it was not well controlled and, therefore, the results required corroboration under more stringently controlled conditions. Hymovitch (11) did this in an extension of Hebb's original research. In the first part of a fairly extensive study he blinded one group at 17 to 18 days of age (early-blinded) and another group at 78 to 80 days (late-blinded). At 21 to 27 days of age half of the early-blinded and late-blinded groups were placed in a large free-environmental area (FE) for 2½ hours a day on 46 to 49 occasions. The FE was a wooden box 6 ft. long, 4 ft. wide, and 6 in. high, covered with hardware cloth and containing playthings within its confines. The playthings consisted of blind alleys, inclined runways, small enclosed areas, and apertures. At 80 days of age, training on an adaptation of the Hebb-Williams apparatus (8) was started. Scores indicated that those exposed to the FE were superior to animals never provided with this experience. No significant differences were observed between the early- and late-blinded groups although the mean error scores of the early-blinded were consistently higher than those of the late-blinded animals.

The second phase of the study consisted of placing six rats in individual stovepipe cages (covered metal cylinders 8 in. in diameter and 16 in. high) designed to restrict total experience, eight in mesh cages designed to restrict movement but permit considerable visual experience, six in enclosed activity wheels to restrict visual experience but allow physical movement while restricting the area, and twenty in FE. All mesh cages were periodically moved through eight locations, six of which were located within FE, in order to provide a perceptually rich environment for these animals. Once the animals were placed in their experimental cages at approximately 27 days of age none was handled. Training on the test apparatus was started at 79 days of age. No differences existed between the FE and mesh-cage groups or between the activity wheel- and stovepipe-cage groups. But the FE and mesh-cage groups, the only groups permitted wide visual experience, were clearly superior to those deprived of visual experience. When given a maze problem to test their rote learning ability, no group differed from any other. This part of the study clearly demonstrates the effect of wide visual experiences in early life on later problem-solving behavior. It further demonstrates that this effect is independent of any handling or relationship established since no animal was touched by the experimenter during the experimental period.

In the third part of the study one group was raised in normal cages but placed in FE for 39 three-hour periods spread over the age range of 30 to 75 days. A second group was kept in stovepipe cages for the same period. From the age of 75 to 85 days all were moved into normal cages and treatment was then reversed during the following 45 days. A third group was restricted to normal cages throughout the 130 days, and a fourth group, which remained in normal cages, was given FE experience during both halves of the study. Results indicated that both the early FE and continued FE groups were clearly superior to the remaining groups, but did not differ from each other; no differences existed between the late FE and continuously restricted groups either. This late FE group was then statistically compared to the restricted or stovepipe-caged group in the second phase of the study, and no differences were found. Hymovitch concludes from this third section of the study that FE experience provided later in life has no effect on test performance; the scores of animals receiving late experience did not differ from those who had no experience.

Hymovitch's work substantiated Hebb's earlier findings that this early perceptual experience has no effect in rote learning situations and that the effects are relatively permanent. In Experiment III the changes produced in problem-solving ability during the first 75 days of life were still present 75 days later. Furthermore, the superior performance of the wider-environment group was not equalled by the group which was deprived in early life, despite an adequate opportunity for experience during later life. "Hence, the effects seem to be relatively permanent and possibly irreversible" (11, p. 320).

Bingham and Griffiths (3) found no differences between FE and restricted groups in discrimination learning, emotionality, and susceptibility to audiogenic seizures. Differences favoring the FE animals were noted when a Warner-Warden maze was used; restricted groups required more trials to reach the criterion. This FE group provided with an inclined ramp, an elevated pathway, and swinging door did not differ from one which had a broken chair, a box, and a broken cage as playthings which indicated to the authors that direct transfer was not the factor responsible for superior performance. They have demonstrated that early perceptual experiences have a beneficial effect but, like Hebb, have concluded that the effect is not found equally in all forms of behavior. Bingham and Griffiths have further demonstrated that "The particular factors constituting the richness of the wide environments did not seem related to the superior maze performance of experimentals over controls" (3, p. 311-312). The authors, however, leave an important question unanswered; they offer no explanation as to why their study is the only one that has found differences in maze learning ability. Hebb (8), Hymovitch (11), and Forgays and Forgays (6) all report no differences in maze performance, a task in rote learning, as a result of rich perceptual experiences early in life.

Forgays and Forgays (6), students of Hebb, sought to delineate still further the possible experimental variables operating. Their subjects were male rats of several litters born approximately the same day, weaned at 26 days, and selected randomly for group placement. A four-story structure was erected in order to subject the appropriate groups to specific environments within the same general environment, that is, the same section of the experimental room. In the stories of the structure were found: (a) FE animals with playthings, and a mesh-cage group; (b) FE animals and a mesh-cage group; (c) playthings and a mesh-cage group; (d) a mesh-cage group. The respective mesh-cage groups could then <u>see</u> FE animals and playthings, FE animals but no playthings, playthings but no FE animals, and an area with neither FE animals nor playthings. A restricted group was housed in laboratory cages with three solid metal walls, a grill top, and a small mesh door. At 90 days of age the animals were removed from their respective environments and placed randomly in large cages. They were then given one week of training on the Hebb-Williams test (10) followed by actual testing on the Rabinovitch (16) adaptation. The results indicate that FE animals that had playthings were better problem-solvers than any other group; the FE rats without playthings were superior to all remaining groups. The restricted group and mesh-cage group raised in a layer with FE animals but no playthings did not differ significantly from each other, and both were inferior to all other groups. The remaining mesh-cage groups, though not different from each other, were inferior to the two FE groups and superior to the restricted group and mesh-cage group mentioned above. Although the authors recognize that this study is not directly comparable to that of Hymovitch (11), they feel it necessary to account for the differences observed in the respective studies with regard to the performance of the mesh-cage group housed with the FE animals with playthings and the FE group. Hymovitch found no difference between these groups in problem-solving behavior, but Forgays and Forgays found the FE group to be superior. The authors state that in their study the mesh groups were housed three per cage restricting them more than Hymovitch who housed them individually. In addition, Forgays and Forgays state that a few animals of the FE group consistently used the mesh cage as a resting spot, lying down on it, which resulted in restriction of the group's perceptual experiences. The results of the study were viewed as further supportive evidence of Hebb's theory, that those animals provided with a perceptually rich or varied environment during early life will be superior problem-solvers as adults.

In the final study to be reviewed, Forgus (7) raised one group in FE with playthings; a second group was raised in the same type of FE but was confined to the inner square foot by glass panes. Group 1 thus had a complex visual and proprioceptive environment and Group 2 a complex visual but minimally stimulating proprioceptive one. The third group confined to a small black box with no furnishings had an environment which provided minimal stimulation in both these areas. Testing which included problem-solving in situations similar to those devised by Maier, as well as form discrimination and generalization showed Group 3 consistently poorer than either of the other groups which differed from each other only on the form discrimination test. On this test Group 2 was significantly superior. Forgus concludes that early experience and learning are important determinants of cognitive ability in the rat, and that the quality of infant experience determines the kinds and number of "hypotheses" they can test when solving problems in adulthood. In accord with these conclusions he explains the difference between Groups 1 and 2 in form discrimination as follows: "... since group 2 animals were physically, but not visually restricted during their development, there was a greater tendency that visual stimuli would be perceptually prominent for them" (7, p. 335). Group 1, on the other hand, had other stimuli which were prominent in addition to visual cues as a result of being raised in an environment which exposed them to more and wider stimulation; although visual cues were important for them, they were not as completely dependent on visual stimulation as was Group 2.

What are some of the possible criticisms which might be leveled against the results of these studies and how would proponents of Hebb's theoretical approach defend their position against these arguments? It might be suggested that superior performance was motivational in origin. With the numerous and varied studies at hand it would appear very unlikely that all animals raised in perceptually enriched environments were more highly motivated on the various tests in which their performance was superior; these tasks include the Hebb-Williams apparatus and its revisions, problems similar to those used by Maier, and some mazes. With respect to the Hebb-Williams test, the criterion of readiness which must be met by all animals prior to testing should have equated all subjects or, at least, minimized motivational factors.

Bernstein and others raised the objection that in Hebb's original study (8) the pet-group was handled more and was, therefore, tamer. His study (2) supported this contention that those handled more frequently will perform better. But Hymovitch (11) handled all of his animals equally and in the second part of his study none was handled. Differences in both instances were in the expected direction. The results do not necessarily indicate that either Hebb or Bernstein is in error, but rather that each is concerned with a variable that has a somewhat similar effect on behavior.

There is the possibility that FE contains elements present in the test situation which would account for the superiority of the FE groups; direct transfer may be operating. If simple transfer such as not entering blind alleys is in operation, it would be expected to show itself in consistently superior maze performance, but this has not been demonstrated. Bingham and Griffiths (3) showed that the elements contained in FE had little to do with the performance in the test situation. Hymovitch (11) and Forgus (7) showed that animals permitted visual experience alone performed as well as those permitted actual contact with playthings. And finally, Forgays and Forgays in comparing the performance of the FE groups with and without playthings state that playthings which are the most obvious agent of direct transfer in the situation apparently benefit the animals over and above the large open field. "Either of these rearing environments, however, leads to superior problem-solving ability. It would appear, then, that the effect of free-environmental experience, as such, is not simple transfer" (6, p. 326).

Superior performance may have resulted from greater opportunity of FE animals for muscular exercise and its concommitant stimulation. Weakening this attack are Hymovitch's (11) results indicating no differences between the activity wheel- and stovepipe-cage groups and none between the FE and mesh-cage groups. Forgus's (7) findings supported this interpretation.

It would then appear that the effects are not the result of motivation, acquisition of specific stimulus-response relationships, or purely motor factors. It rather appears that the differential opportunities for perceptual learning were responsible for the results. Experimental evidence (8, 11) further suggests that these wider experiences must occur early in life, and when provided at maturity differences in performance are not erased. Finally, results indicate (9, 11) that these effects are fairly permanent, that they persist over relatively long periods of time. Hebb's theory, which grew out of his first exploratory studies, is summarized by Beach and Jaynes who state that it predicts that animals permitted large amounts of perceptual experience during early life will prove better learners than those deprived of such experience. "Further, it is predicted that the magnitude of this facilitative effect is, within limits, inversely related to the age at which the perceptual experience is gained" (1, p. 255). It is the purpose of the present study to attempt to define these limits and further, to investigate the effect of variations in amount of FE experience on later learning, as measured in problem-solving situations of the Hebb-Williams type.

CHAPTER III

EXPERIMENTAL DESIGN AND METHOD

Housing

The FE or experimental area was a four-story structure measuring 5 ft. in height, 4 ft. in width, and 2 ft. in depth as described by Forgays and Forgays (6). It was a white wooden structure with 1/4-in. wire mesh sides, masonite floors painted black and covered to a depth of 1/2-3/4 in. with wood shavings. Each level within the structure was 12 in. high with its ceiling serving as the floor for the level above. (See Fig. 1.) Within these areas were playthings designed to duplicate those of the above mentioned study. They consisted of a tunnel with wood sides and masonite top, a see-saw, and a small enclosed area open at the top measuring 12 in. square with archway entrances and two 1/4-in. plywood baffles jutting into the area. All were 12 in. long, painted white, and constructed of 3/4-in. lumber except where indicated. The tunnel and enclosed area were 4 in. high. The see-saw measured 6 in. in height. Placement of the playthings is shown in Fig. 1.

The control group was housed in standard laboratory cages (9x10x16 in.) fitted with masonite sides. Laboratory paper was placed above and below each of the cages

Fig. 1. Photograph of the free-environmental structure.

restricting the animals' visual environment to the area within the cage. Except for the periods during which the various experimental groups were placed in FE, they were housed and treated exactly as the control group. Males and females of each group were housed separately with each cage containing 7-8 animals. The fourteen cages required for the seven groups were placed on a double tiered rack; eight on the upper and six on the lower level with no special attention given to the cage placement, since the animals could not see outside.

Animals

One hundred five albino rats of the Charles River strain were used. This number contained fifteen litters of seven animals each born the same day. Each litter contained 3-4 animals of each sex for a total of 52 males and 53 females. A split-litter control was exercised so that each of the seven groups, described below, contained only one animal of each litter. All were weaned at 21 days of age and arrived at the laboratory the following day. In the course of the study two animals died.

All were fed Purina Laboratory Chow each morning. The ration per cage was 1/10 the approximate weight of an average rat in grams, as given in an age-weight chart, multiplied by the number of animals per cage. An additional gram was allotted those in cages to allow for food falling through the 1/2 in. wire mesh floor; water was available at all times. This diet was supplemented weekly with lettuce. Cage doors were opened twice daily, at feeding time and again in the evening, to permit inspection.

FE Experience

After having spent varying lengths of time in crowded cages, an environment both visually and physically restrictive, each of the six experimental groups was placed in FE. The three odd-numbered groups (I, III, V) were exposed to this environment for 20 days, the even-numbered groups (II, IV, VI) for 10 days. Group VII, the control group, never entered FE. The groups were so arranged that both a 10- and a 20-day group received their FE experience at the same mean age; for Groups I and II this was 35 days, for Groups III and IV it was 55 days, and for Groups V and VI it was 75 days. The various groups were placed in FE as follows: Group I from 26 to 45 days; Group II from 31 to 40 days; Group III from 46 to 65 days; Group IV from 51 to 60 days; Group V from 66 to 85 days; and Group VI from 71 to 80 days. The 20 days which Groups I, III, and V spent in FE were divided into four 5-day periods and at the conclusion of each period the animals were moved to a different level within the experimental structure. The matching 10-day groups, therefore, entered FE at the start of the second 5-day period and were removed at the conclusion of the third period. The placement of the groups for each of the 5-day periods is shown in Table 1. All groups were handled as little as possible, but to equate for this variable it was necessary to handle all animals six times, the number required in moving a 20-day group into, within, and out of FE. When the experimental groups were removed from FE they were returned to their cages and treated exactly as the control group.

Test Apparatus

The closed-field testing apparatus was the same as that devised by Hebb and Williams (10) and modified by Rabinovitch and Rosvold (17). It consisted of a box with entrance and food compartments at opposite corners of an open field. It is shown in Fig. 2. The floor of 1/4-in. plywood was unpainted. The walls, painted black, were made of 1/2-in. plywood 4 in. high. There were thirty-six 5-in. squares outlined in black on the floor of the open field which served to define error zones and act as markers for accurate and reliable placement of barriers. The barriers used to construct the various problems were painted black, made of 1/2-in. plywood 4 in. high. They were constructed so that when set on edge they reached from the floor to the

TABLE 1

FREE ENVIRONMENT PLACEMENT

Group	Days of Age	Five Day Period I	II	III	IV
		Level			
IM	26-45	1	2	3	4
IF	" "	4	3	2	1
IIM	31-40		1	4	
IIF	" "		4	1	
IIIM	46-65	4	3	2	1
IIIF	" "	1	2	3	4
IVM	51-60		4	1	
IVF	" "		1	4	
VM	66-85	1	2	3	4
VF	" "	4	3	2	1
VIM	71-80		1	4	
VIF	" "		4	1	
VIIM) Control					
VIIF)					

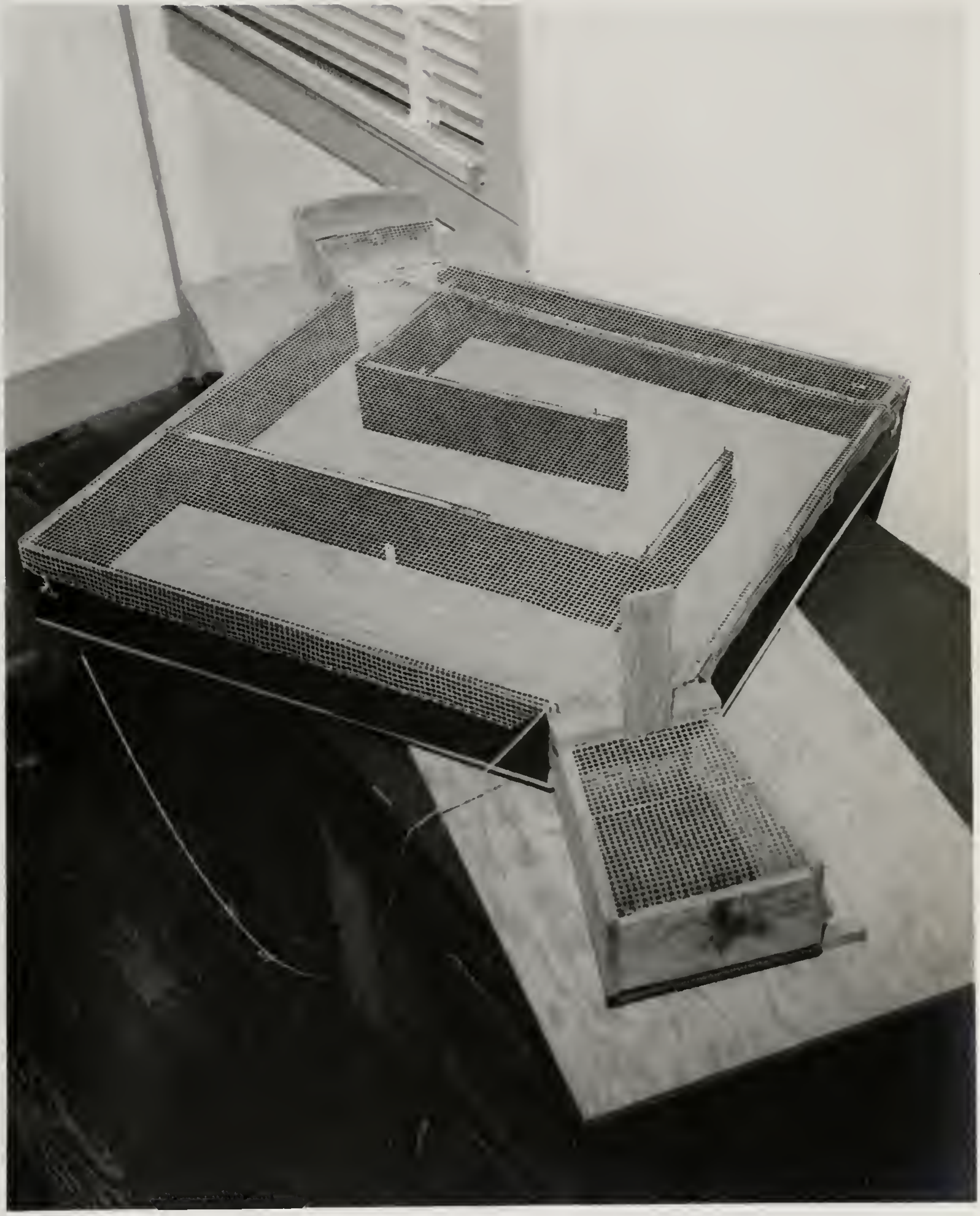

Fig. 2. Photograph of test apparatus.

1/4-in. screen top of the box. There were 14 barriers varying in length as follows: 3 barriers, each 5 in. long; 4 barriers, each 10 in. long; 3 barriers, each 15 in. long; 2 barriers, each 20 in. long; and 2 barriers, each 25 in. long. A small piece of sheet metal, 2x1/2 in. was nailed to the bottom of each barrier to insure its standing on edge. To prevent its being moved once the screen top was fastened, a 3/4-in. brad was put into the top of the barrier at each end so that it engaged the mesh top.

The practice and test problems were constructed by placing various barriers within the open field in defined locations (17). The practice problems, although similar in nature to those used in testing, were simpler. They generally consisted of fewer barriers and required the animals to make fewer turns. The animals on release from the starting box found their way around the barriers to the food box. (See Fig. 3.)

In the original article by Hebb and Williams, the closed-field test is described as "a method of evaluating animal intelligence which appears to have several important advantages, of efficiency, and validity" (10, p. 59). In its general approach, it is claimed to be applicable to any species. They further state, "The most valid and valuable ratings of human intelligence are not based on learning scores but on an analysis of performance in a

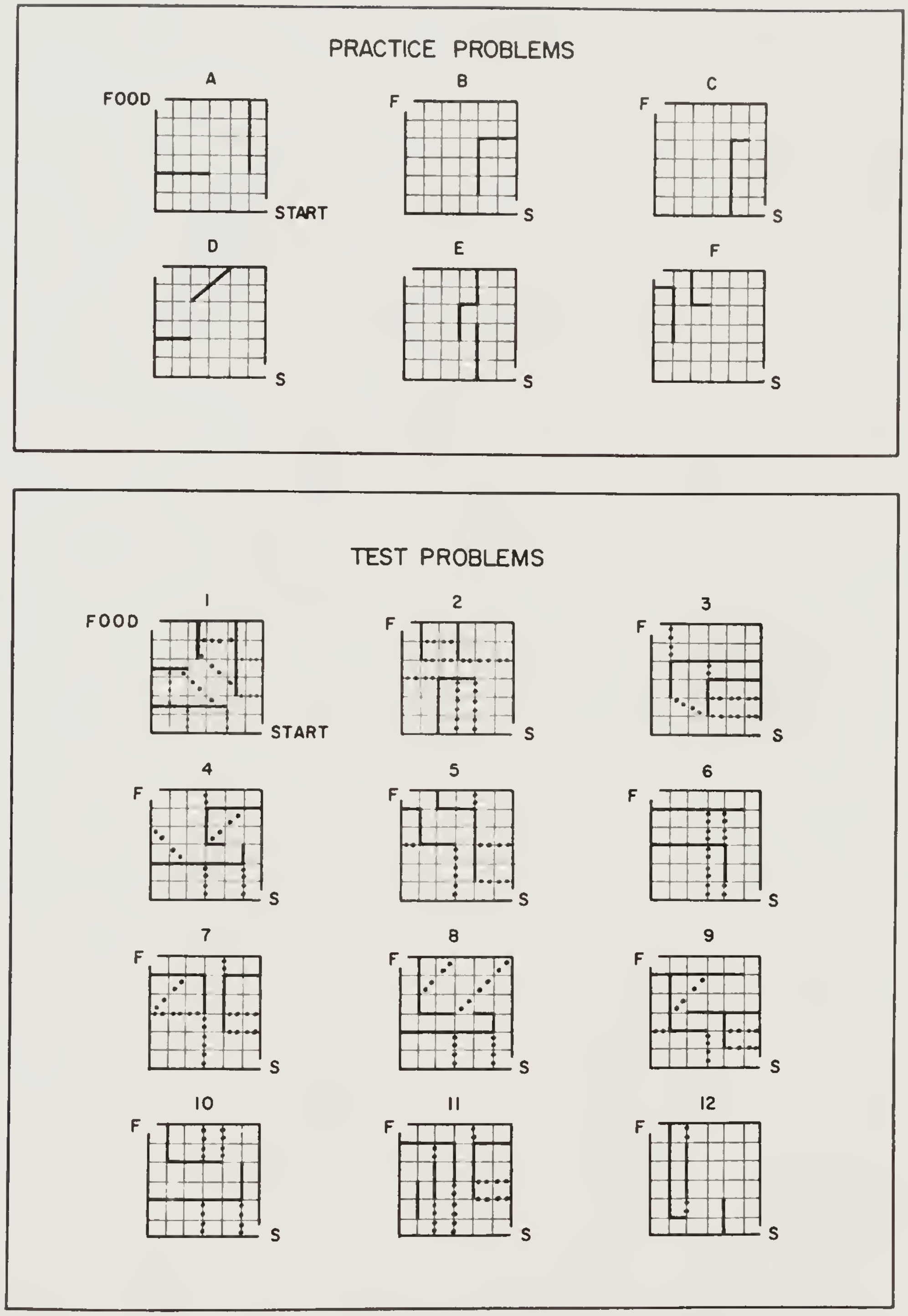

Fig. 3. Floor plan of practice and test problems.

large number of short tasks." Rote learning scores such as those obtained in maze learning may be a measure of timidity, of need for food, or a complex of these with intellectual factors. This method minimizes motivational variations and bases its score on a large number of performances. This is problem-solving as contrasted to rote learning (8).

The test-retest reliability of the Hebb-Williams apparatus is .84, as reported by Hebb (8). In the most recent standardization, Rabinovitch and Rosvold (17) found a rho of .84 when all animals (normals, brain operates, and free-environmental) were compared. This was reduced to .80 when only the unoperated animals were considered. The ability of the test to differentiate the various groups, and its high test-retest reliability are both indicators of its essential validity.

Those animals making better scores may have superior perceptual capacities--the situations were meant to make a fairly immediate visual solution possible--or they may have a better immediate memory of the preceding run. However, in either case it may be assumed that an intellectual function is measured which is not equivalent to the result of long term training in the test situation. Motivation did not appear to be an important variable since the animals were not tested until all signs of timidity had disappeared in the training period. There was no indication that those who made poorer scores were less eager for food. There were, also, no indications of any exploratory activity, and none that the poorer scorer tended to follow the walls--when all barriers were removed all animals went directly to the food (10).

The test, then, appears to have reliability, some degree of validity, and be well suited for studies of this type.

Pre-test Training

Because of the large number of animals used in the study, it was impossible to train and test all of them at the same time. It was, therefore, decided to begin the training and testing of half of each group at 90 days of age, five days after the last FE group was returned to its cages. The animals included in this early-tested group were the females of Group I, males of Group II, females of Group III, and so on. Half of Group VII consisting of males and females was also included. Testing was completed on the early-tested group before the remaining animals, the late-tested group, were started on the pre-test training. This training began at the age of 116 days, 31 days after the last group had been removed from FE.

The pre-test training period, consisted of adaptation sessions and preliminary runs on the practice problems. Its purpose was to teach the animals where food was to be found, to establish the habit of eating in the food box, and to adapt them to the apparatus and handling, so that when they were released from the starting box they would go to the food with a minimum of exploratory behavior and without fear (17).

The adaptation sessions consisted of placing 3-4 rats in the box simultaneously after 23 hours of food deprivation. They were then allowed to find their way around the barriers of problems A-F (Fig. 3) to the food compartment where they were permitted to eat moist ground food for 45 minutes. Thereafter, they were never fed in their cages. Problem A was set up on the first day, problem B on the second, and so on until the series was completed. This procedure was repeated until all rats ran to the food box immediately upon being released.

As soon as they were eating well and gave the impression of being adapted to the apparatus, the animals were run individually in the preliminary runs with as much handling as possible. Time was then recorded from release until the first bite of food. They were permitted a few bites and were then replaced in the entrance compartment, being timed as previously. This process was repeated nine times, once a day, until all animals reached the criterion of making nine runs to food in a total of 60 seconds or less on two consecutive problems. When an animal was not running as fast as it should, eating time of 30 minutes was reduced. For those that reached the criterion training was continued, but the usual nine runs were reduced to three per practice problem. Previous work (17) indicates that subsequent test scores are not influenced by these extra runs and that those animals who reach the criterion quickly are no more likely to perform better than others on the test problems.

Testing Procedure

The early-tested animals required 11 days to reach the training criterion, and the late-tested group required 10 days; therefore, testing began at 102 and 127 days of age, respectively. Following 23 hours of food deprivation each animal was given eight runs in the first problem situation and then allowed to eat in a movable and duplicate food box for 30 minutes. Approximately 23 hours later the procedure was repeated with the second problem, and so on until all 12 problems were completed at the rate of one a day.

An attempt was made to vary the order in which the groups were exposed to the test problems so that each group would be placed in as many different serial positions as possible while maintaining an approximate 23-hour hunger drive. There was some difficulty in this since testing a single group of 7-8 animals took approximately one hour; therefore, no group's position could be shifted extensively from day to day.

The animal's score in each problem was the total number of error zones entered. Time was not recorded. An error was counted each time the animal's two forefeet crossed into an error zone. The error zones are indicated in Fig. 3 by broken lines. Where an alley contains two error zones, two errors were scored if the animal crossed the second line, but none was scored when he emerged from the alley through the first error zone. If, after having emerged with both forefeet, the animal turned around and went back, an additional error was scored. The animal's score on the entire test was the total number of error zones entered on the 12 problems. These provided the critical data in terms of which the hypothesis was evaluated.

CHAPTER IV

RESULTS

While planning the study, it was recognized that although the total number of animals used would be large, each group would contain only a small number of subjects. Since the assumptions underlying traditional statistical procedures would be difficult, if not impossible, to satisfy with such small groups, other methods of analysis were sought. Non-parametric statistical methods, as described by Moses (14), appeared applicable in the present situation since tests of significance do not depend upon assumptions concerning the population distribution. Of the methods described, Wilcoxon's matched pairs signed ranks test (24) appeared the most adequate since it demanded a more stringent experimental control, that of a split-litter control in the present study. This technique consists of computing the difference between the scores of the various pairs, always subtracting in the same direction. These differences without regard to sign are then ranked, and the ranks derived from scores of the same sign are summed. The smaller of these two totals is then used directly in entering the probability tables supplied by Wilcoxon (25). In some cases our own probability values had to be computed from the formula he provides since some comparisons contained a number of pairs greater than provided for in his tables. A single example of the computations involved in this analysis is provided in Appendix Table 2.

The results of the analysis in which each of the groups was compared to every other group are presented in Table 2. From this table we can see a marked tendency toward superior performance in the test situation by Group III, exposed to FE for 20 days from 46 to 65 days of age. This group is significantly better than Groups V and VII and shows a tendency toward superiority over Groups I, II, and VI. Groups III and IV did not differ in their performance. Group IV which was exposed to FE for 10 days from 51 to 60 days old and, therefore, received its experience at the same mean age as Group III, performed significantly better than the control group which was never exposed to the experimental environment. It would then appear that a 10-day exposure to this perceptually rich environment at an age approximating 55 days has an effect sufficient enough to differentiate this group from those restricted throughout. But exposure for 20 days results in performance that tends to be superior to that of all groups exposed at other ages. Exposure at very early ages (26 to 45 days) or at ages close to maturity (66 to 85 days),

TABLE 2

GROUP BY GROUP COMPARISONS USING A
NON-PARAMETRIC MATCHED PAIRS
STATISTICAL TECHNIQUE

	I	II	III	IV	V	VI	VII
I (20, 35)**		>.05		>.05	>.05	>.05	>.05
II (10, 35)				>.05	>.05	>.05	>.05
III (20, 55)	>.05*	>.05*		>.05	<.05	>.05*	<.01
IV (10, 55)					>.05	>.05*	<.02
V (20, 75)						>.05	>.05
VI (10, 75)							>.05*
VII (Control)							

Note.--Where differences are or tend to be significant groups along the vertical axis were superior.

*Approaches significance.

**Length of and mean age at FE exposure.

whether of 10- or 20-days duration, does not improve performance; none of these groups was significantly different from the restricted group. When the groups with the same mean exposure age (I and II; III and IV; V and VI) were combined and compared with the other two groups as in Table 3, exposure at 55 days of age is seen to result in performance in the problem-solving or testing situation which is significantly superior to the performance of those groups exposed at 35 or 75 days of age. However, the length of exposure, per se, whether 10 or 20 days, without regard to the age at which it occurs, has no apparent effect on problem-solving behavior. The animals on whom testing was started when 102 days old did not differ in their performance from those started at 127 days of age, neither were there any sex differences. These final comparisons are based on _t_ tests.

TABLE 3

COMPARISONS BASED ON MEAN DAYS OF AGE AT WHICH GROUPS WERE EXPOSED TO FREE ENVIRONMENT (NON-PARAMETRIC MATCHED PAIRS STATISTICAL TECHNIQUE USED)

	Days of Age		
	35	55	75
35			>.05
55	<.05		<.02

Note.--Where significant differences are indicated groups along the vertical axis were superior.

CHAPTER V

DISCUSSION

In general agreement with the findings of Hebb (8, 9), Hymovitch (11), and Forgays and Forgays (6) there seems to be little question that free-environmental or perceptually enriched experiences in early life are reflected in superior problem-solving ability in the mature rat. However, the present study has served the function of defining the previously nebulous period during which these experiences will affect subsequent performance; it served to delimit within a fairly restricted range the age at which exposure to this enriched environment produces greatest enhancement in problem-solving behavior at maturity. This age range is roughly between 46 to 65 days, and does not appear to support fully Hebb's general notion that the size of the effect is inversely related to the age at which these experiences are provided.

It might be suggested that superior performance was motivational in origin. However, all animals met the same criterion of readiness, nine runs in a total of 60 seconds or less on two consecutive training problems. This criterion should have equated the animals or, at least, minimized motivational factors. Qualitatively, no exploratory behavior was observed in any of the animals during the testing period.

Bernstein (2) showed that tamer groups of animals perform significantly better than less tame groups. In the present study the variable, handling, was held constant. Each animal was handled six times from the day they were placed in the various groups, at 22 days of age, through the start of preliminary training, at 90 or 116 days of age. It may be speculated that the age at which handling took place was an important variable, and that as the animals grew older it had a more taming effect. This would account for the superiority of the 55 day group when compared with the 35 day group. But, it would also lead to the prediction that the 75 day group would be superior to all younger groups. This prediction is not borne out in the data which indicates that the 55 day group was significantly superior to either of the other groups. It might then be suggested that the handling schedule of the 55 day group had the greatest taming effect. If this was true the control group which had the same handling schedule should be indistinguishable from it in test performance. This is contradicted by the data.

Had transfer or the opportunity for muscular exercise been important variables all experimental groups should have been superior to the control group. In addition all 10- and all 20-day groups should have performed equally. Both of these "predictions" are contradicted by the data.

It then appears that the effects are not the result of motivational differences, the operation of transfer, or motor factors. It rather appears that the opportunity presented the various groups for perceptual learning was responsible for the results.

Attempts to account for results in terms of relevant and prominent stimuli are seen in the studies of Forgus (7) and Thompson and Heron (22). Discussing the findings that free-environmental animals did poorer on a form discrimination task, Forgus (7) states, "since group 2 animals were physically, but not visually, restricted during their development, there was a greater tendency that visual stimuli would be perceptually <u>prominent</u> for them" (7, p. 335), while the free-environmental animals had additional prominent stimuli because they had been exposed to many more. In accounting for the poor performance of restricted dogs, Thompson and Heron (22) state that the exact nature of the deficit shown by these dogs is not easily defined, but appears best described as a lack of ability to discriminate relevant from irrelevant aspects of the environment.

That exposure to the experimental environment had no effect on the young animals (Groups I and II) may be explained in either of twc ways neither of which can be validated from the data of this experiment. It is possible that these very young animals (26 to 45 days old) were incapable of organizing the complex stimuli to which they were exposed into a meaningful or useful pattern. If this is true, then it may be concluded that they were too young or maturation had not progressed far enough to enable them to benefit from this type of experience.

The second possible reason for no improvement in problem-solving behavior is that during the period of restriction following FE experience, reliance upon visual cues disappeared since they were no longer important for the animals. This account differs from the first in that it assumes an organization of the stimuli by the young animals, but that in the following period the usefulness of visual cues practically disappeared. Therefore, when placed in a situation in which these cues were important, hypotheses other than those based on visual stimuli were tested since they stemmed from cues which had become important in the animals' behavioral repertoire during the long period of restriction. From this account it would appear that after additional visual experience, problem-solving ability should improve so that their performance would not differ from that of the 55 day old group. This conclusion, which is easily testable, stems from the assumption that an organization of stimuli was previously present; that the animals had, in essence, derived some benefit from their experience; and that only relearning the importance of visual cues was necessary. In contrast, the first account based on an inability to organize the stimuli would not predict improved performance relative to this 55 day old group, since new learning, rather than relearning, is necessary which appears unlikely to occur since Hymovitch (11) showed that exposure after 85 days of age following previous restriction has no beneficial effect on problem-solving behavior.

The present study indicates that if the first exposure to extensive visual stimulation comes as late as 66 to 85 days there is no enhancement in problem-solving ability. These results can again be accounted for in terms of prominence of stimuli. Since these animals were never required to use visual stimuli to any extent, they never became important or prominent for them, and by the time the animals were placed in the free-environmental situation they were set or fixed in relation to the stimuli to which they would attend. In this situation, then, visual cues were of minor importance to the animals and performance based upon them was, therefore, poor.

Changing our frame of reference and labelling as speculation that which follows, we may ask how the present results and attempted explanations fit with what we know about childhood behavior and development.

Our first explanation of the poor performance of early-exposed animals was based on the assumption that they were unable to organize the stimulus field and, hence, were incapable of benefiting from this experience. In line with this, one is reminded of James's description of the infant's consciousness as a "blooming buzzing confusion" probably incapable of separating or differentiating various aspects of the environment. We are allaware that many cues which stimulate adults or even older children apparently escape or, at least, do not affect the young child's behavior. These environmental features, behaviorally, are meaningless for him because he is incapable of organizing them into a meaningful pattern. Even with practice many forms of behavior are not improved as McGraw (12) has shown, because maturation has not progressed far enough to permit beneficial effects to be derived from this experience.

The second attempt to account for the poor performance of the early-exposed animals assumed that they were capable of organizing the stimuli, but that during the following period these same cues, because they were no longer depended upon, lost their importance or prominence. This can be summarized in terms of forgetting through lack of practice. The young child learns various routines and habits with comparative ease, but constant repetition is necessary if this behavior is to have any permanence. He is extremely flexible and adaptable in that a pattern which is new, different, or even the opposite of the previously established one can be learned with relatively little difficulty. Stimuli, at this age, which were previously unattended and unimportant, can suddenly spring into prominence and those of previous importance, slip into obscurity.

Older-exposed animals, it was suggested, may be set or fixed in relation to the stimuli to which they attend or react. Still in the province of speculation, we see its counterpart in older children who are fairly close to maturity. Social learning is just about completed by this age, methods of adaptation and adjustment are well rooted, and they are more difficult to change. The comparative speed with which young children respond in therapy as compared with that of the individual near maturity supports the position that firmly entrenched patterns of behavior are less susceptible or, at least, more difficult to change.

Present results indicate that there is probably a period when environmental influences have a tremendous impact upon the individual which is relatively permanent. In the rat, this period appears to be about midway between weaning and maturity. Speculating with reference to children, the comparable period would extend roughly from

5 to 9 years of age. In support of the importance of this age, Cole and Morgan (5) state that the period between entrance to primary school and adolescence is extremely important in the development of social behavior, and Wechsler's curve of mental growth shows this period to include the start of, as well as, a period of rapid growth (23).

But stating that all behavior is affected equally and during the same short age span is to defend an untenable position. A firmer and sounder approach is perhaps, to postulate critical periods in development; a position which is not new and which is supported by physiological as well as psychological evidence. A recent article (26) reported that a wide range of congenital abnormalities can be produced in baby rats by subjecting the mothers to severe deficiencies of folic acid, a B vitamin, for as little as two days during a "critical period" of pregnancy. These deformities include hair lip, cleft palate, extra and fewer digits, and club feet. It was known previously that this could be done, "but scientists had not realized how narrow a time may be involved." There are no significant abnormalities if the deficiency occurs before the seventh or after the twelfth day of pregnancy. A 24 hour deficiency from 7 to 12 days after the start of pregnancy had no effect, but a 48 hour deficiency "produces death or devastating abnormalities" in 70-100% of the animals. The mothers suffered no ill effects.

In psychological literature, Scott and Marston (18) divide the development of the puppy into critical periods according to the kinds of behavior that are possible. The first is the neonatal period lasting approximately 14 days or up to the opening of the eyes. During this time the animal is somewhat isolated from the environment. A transition period follows and lasts until about 3½ weeks of age when conditioning is said to become possible. This period lasts until the puppy leaves the nest and first notices observers, which marks the beginning of the socialization period. It is during this time that the first extensive contacts with individuals other than the parents take place, and it is described as a critical period affecting the future social adjustment of the animal. This period, ending with weaning at 8 to 10 weeks of age, is followed by the juvenile period which lasts until sexual maturity. Following this, the animal enters the adult stage.

In the area of human behavior, Freud's stages of psychosexual development are well known and need not be reviewed here. Other authors have also made use of the concept of critical periods. Stratton (21) in his discussion of children reared in isolation stated, "Lack of association with adults during a certain critical period of early childhood [italics mine], it seems likely, produces in some or all normal children marks like those of congenital defect" (21, p. 597). On the same topic, Maslow and Mittleman state, "Whether this feeble-mindedness is permanent or not seems to depend on the child's age when social isolation begins [italics mine]." If it starts after the development of speech "it is remediable for a long time after, likely for several years" (13, p. 317). It appears possible, then, that there are ages when specific types of learning are possible and easy, but once this critical period has past this learning is extremely difficult, if not impossible.

In terms of the present study, it appears that there is a critical period in the development of rats during which visual learning or sensitivity to visual cues takes place. This period extends approximately from 46 to 65 days of age. At earlier or later ages, it was seen, this learning or sensitivity does not take place. Leaving the specific results of the study and generalizing from them, it appears that there are ages when the individual is too young to benefit from environmental experiences and that when he reaches a certain age environment plays a relatively minor role, that is, his behavior is patterned, and within limits of severity, contemporary environment does not alter it to any appreciable degree or permanently.

The present study indicates a need for research along the following lines: (a) investigations to determine the reason for unimproved problem-solving ability in rats exposed to a rich visual environment at young ages, (b) systematic and comparative studies to determine other influences that affect behavior without restricting the behavior studied to problem-solving, (c) comparative research designed to investigate the existence of critical periods in development.

CHAPTER VI

SUMMARY

The purpose of the study was to test Hebb's general notion that the earlier rats are exposed to a perceptually enriched environment, the greater will be their problem-solving ability when mature. The specific hypothesis tested was that enhancement of the problem-solving ability of mature rats is a function of the amount of this free-environmental experience and the age at which it is provided. Six experimental and one control group, consisting of fifteen animals each, were used in the study. A split-litter control was exercised. All groups, except the controls, were placed in a large free-environmental area containing playthings as described by Forgays and Forgays (6), for 10 or 20 days at mean ages of 35, 55, or 75 days. The control group was housed in standard laboratory cages fitted with opaque sides; the tops of the cages were always covered with laboratory paper. The experimental groups were also housed in these cages except for the period spent in the free-environmental area. All animals were handled the same number of times during rearing.

Half of each group was tested at 102 days of age and half at 127 days on the Hebb-Williams closed-field

test, as revised and standardized by Rabinovitch and Rosvold (17).

The results may be summarized as follows:

a. Animals tested at 102 days of age did not differ from those tested at 127 days (see p. 35 and Appendix Table 4).

b. Sex does not influence performance in the test situation (see p. 35 and Appendix Table 5).

c. Length of exposure did not appear as a significant variable (see p. 35 and Appendix Table 3).

d. Age at exposure appeared as a significant variable--the group receiving free-environmental experience at the mean age of 55 days, i.e., Groups III and IV combined, performed significantly better than those receiving it at 35 or 75 days (see p. 35-36 and Appendix Table 3).

The study supports Hebb's theory that wide perceptual experience provided early in life has a beneficial effect on the problem-solving ability of mature rats. It does not support his notion that the enhancement is inversely related to the age at which this experience is received. Unimproved performance by groups provided with this experience at very early ages or at ages close to maturity, was accounted for in terms of relevant or prominent stimuli.

The experimental hypothesis tested was: The effect of free-environmental experience on problem-solving ability of mature rats is a function of the length of this experience and the age at which it is permitted. This predicted that the age at the time of exposure, the length of exposure, or an interaction of these variables would be significant. The experimental results support the prediction made with respect to the age variable.

APPENDIX

TABLE 1

TEST SCORES

	Groups						
	I	II	III	IV	V	VI	VII
Litter							
1	83(M)	112(M)	88(M)	124(M)	130(F)	124(F)	215(F)
2	145(M)	Died	129(M)	120(M)	142(F)	149(F)	158(F)
3	135(M)	95(M)	128(M)	96(M)	129(F)	163(F)	240(F)
4	188(M)	177(M)	122(M)	153(M)	169(F)	150(F)	143(F)
5	153(F)	185(F)	140(F)	125(F)	162(M)	100(M)	137(M)
6	136(F)	122(F)	100(F)	113(F)	115(M)	133(M)	154(M)
7	139(F)	136(F)	110(F)	176(F)	116(M)	112(M)	131(M)
8	112(M)	166(F)	116(F)	151(F)	186(M)	180(F)	180(M)
9	129(M)	195(M)	149(M)	125(M)	157(F)	175(F)	136(F)
10	123(F)	136(F)	104(F)	116(M)	98(F)	148(M)	190(M)
11	191(F)	121(F)	154(M)	151(F)	161(M)	175(M)	162(F)
12	149(F)	135(F)	156(F)	119(F)	111(M)	105(M)	144(M)
13	138(M)	106(M)	104(M)	112(M)	117(F)	130(F)	129(F)
14	139(M)	125(M)	103(M)	141(M)	127(F)	Died	130(F)
15	113(F)	132(F)	151(F)	126(F)	129(M)	148(M)	131(M)

TABLE 2

GROUP I COMPARED WITH GROUP II BY MEANS OF THE WILCOXON MATCHED PAIRS SIGNED RANKS TEST

Pair	Group I	Group II	Diff.	Rank
1	83	112	-29.0	8
2	145	Died		
3	135	95	40.0	11
4	188	177	11.0	2
5	153	185	-32.0	9.5
6	136	122	14.0	5
7	139	136	3.0	1
8	112	166	-54.0	12
9	129	195	-66.0	13
10	123	136	-13.0	3
11	191	121	70.0	14
12	149	135	14.0	5
13	138	106	32.0	9.5
14	139	125	14.0	5
15	113	132	-19.0	7

Sum of ranks with less frequent sign=52.5

$P > .05$

TABLE 3

GROUP COMPARISONS

Groups	Sum of Ranks	N	P
I vs. II	52.5	14	>.05
I vs. III	28.5	15	>.05*
I vs. IV	43.5	15	>.05
I vs. V	48.0	15	>.05
I vs. VI	47.0	14	>.05
I vs. VII	41.0	15	>.05
II vs. III	24.0	14	>.05*
II vs. IV	39.0	14	>.05
II vs. V	44.5	14	>.05
II vs. VI	45.5	13	>.05
II vs. VII	33.5	14	>.05
III vs. IV	48.0	15	>.05
III vs. V	25.0	15	<.05
III vs. VI	26.0	14	>.05*
III vs. VII	13.0	15	<.01
IV vs. V	36.0	15	>.05
IV vs. VI	26.5	14	>.05*
IV vs. VII	18.0	15	<.02
V vs. VI	34.5	14	>.05
V vs. VII	31.0	15	>.05
VI vs. VII	27.0	14	>.05*
10 vs. 20 days old (II, IV, VI vs. I, III, V)	397.5	43	>.05
35 vs. 55 days old (I, II vs. III, IV)	126.5	29	<.05
35 vs. 75 days old (I, II vs. V, VI)	184.5	28	>.05
55 vs. 75 days old (III, IV vs. V, VI)	103.0	29	<.02

*Approaches significance

TABLE 4

EARLY-TESTED COMPARED WITH LATE-TESTED ANIMALS

	Mean	S_{D_M}	*t*	P
Early-Tested	134.92	5.48	1.29	>.05
Late-Tested	142.00			

TABLE 5

MALES COMPARED WITH FEMALES

	Mean	SD_M	*t*	P
Males	133.55	198.06	.05	>.05
Females	143.48			

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BIOGRAPHICAL SKETCH

Bernard Eingold was born July 19, 1927, in New York City. He graduated from William Howard Taft High School there in 1944. He then attended New York University, College of Arts and Pure Science, until enlisting in the United States Navy in June, 1945. Returning to New York University in February, 1947, after being discharged from service, he received his Bachelor of Arts Degree in the spring of 1949 with a major in psychology.

Mr. Eingold received his Master of Arts Degree in psychology from the University of Missouri in August, 1951 after which he attended the University of North Carolina for one year. He has been in attendance at the University of Florida since the fall of 1952.

He was elected to the honorary social science society at the University of Missouri; Alpha Kappa Delta, the honorary sociology society at the University of Florida; and Psi Chi, the national honorary society in psychology. He is also an associate member of the Florida Psychological Association and the American Psychological Association.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of the committee. It was submitted to the Dean of the College of Arts and Science and to the Graduate Council and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 4, 1956

C. F. Byers
Dean, College of Arts and Science

Dean, Graduate School

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